IEA Wind Task 36 "Probabilistic Forecasting Games and Experiments" initiative
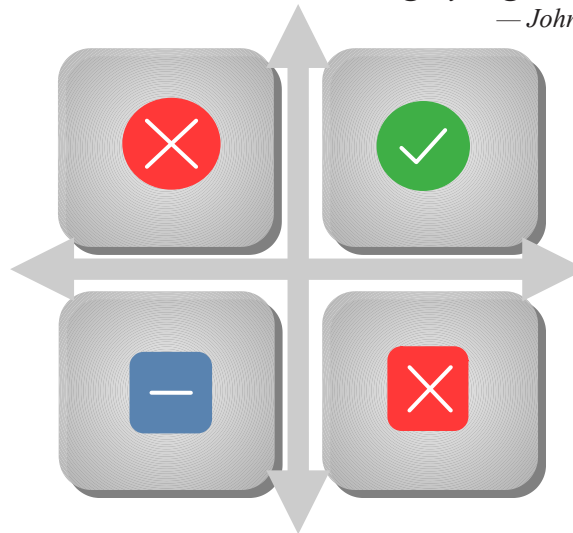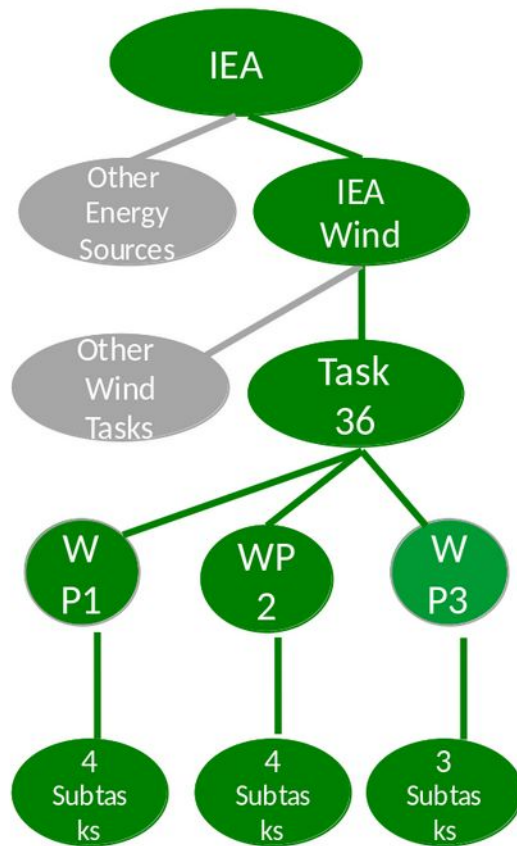
EMS Annual Meeting 2021: Session E2.2 "Dealing with Uncertainties"
– 6t September 2021 –

Corinna Möhrlen, WEPROG
Ricardo Bessa, INESC TEC
Gregor Giebel, DTU
Nadine Fleischhut, MPI

'It is better to be roughly right than precisely wrong.'
— John Maynard Keynes (attributed)

IEA Task 36 - Forecasting for Wind Energy

What is the IEA (International Energy Agency)? (www.iea.org)

- International organization within OECD with 30 members countries and 8 associates
- Promotes global dialogue on energy, providing authoritative analysis through a wide range of publications
- **One activity: convenes panels of experts to address specific topics/issues**

Task 36: Forecasting for Wind Energy: (www.ieawindforecasting.dk)

- One of 17 Tasks of IEA Wind: https://community.ieawind.org/home
- Phase 1: 2016-2018; Phase 2: 2019-2021
- Operating Agent: Gregor Giebel of DTU Wind Energy
- Objective: facilitate international collaboration to **improve wind energy forecasts**
- Participants: (1) research organization and projects, (2) forecast providers, (3) policy-makers and (4) end-users & stakeholders

Task 36 Scope: Three "Work Packages"

- WP1: Global Coordination in Forecast Model Improvement
- WP2: Benchmarking, Predictability and Model Uncertainty
- **WP3: Optimal Use of Forecasting Solutions**

Task homepage: http://www.ieawindforecasting.dk/

...the overarching goal is to demonstrate the value of using probabilistic forecasts in the Renewable Energy Sector

→ **What we develop: unified and inter-disciplinary approaches**

→ **How we work: merge of separate fields and competencies**
Energy-Meteorology
Statistical Mathematics
Behavioural & Cognitive Science

→ **What us use: behavioural decision experiments**
* simulate real-time problems ("gamification") for specific user groups
* formulate strategies for applications & research
* design experiments to study communication and knowledge gaps

Forecast Games and Experiments Initiative

Research Questions

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How are probabilistic forecasts used & when do they benefit decisions?
- Decision outcomes: Do users make better decisions und in which forecast situations?
- Risk preferences: Do they decide more risk averse or risk seeking?
- Decision strategies: What cues ("predictors") do they use and how?
- Representation format: Which representations work best?

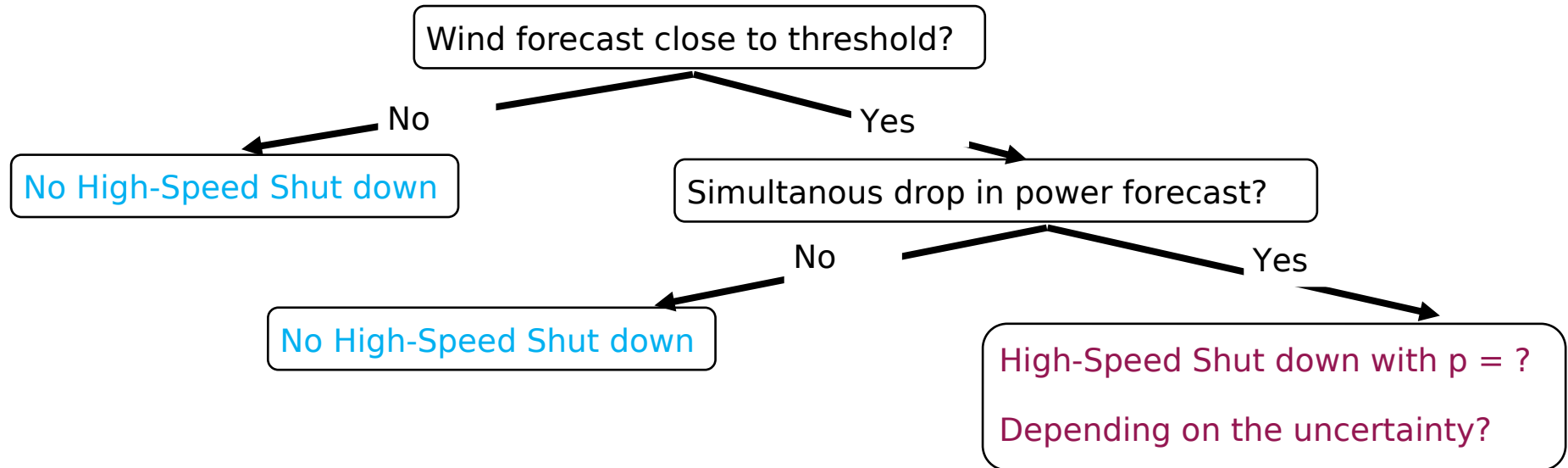**Do probabilistic forecasts allow better learning from feedback?**
- How confident are users in their decisions?
- How well can they learn to calibrate their confidence? (Knowing when you don't know)
- How do users react to failure?

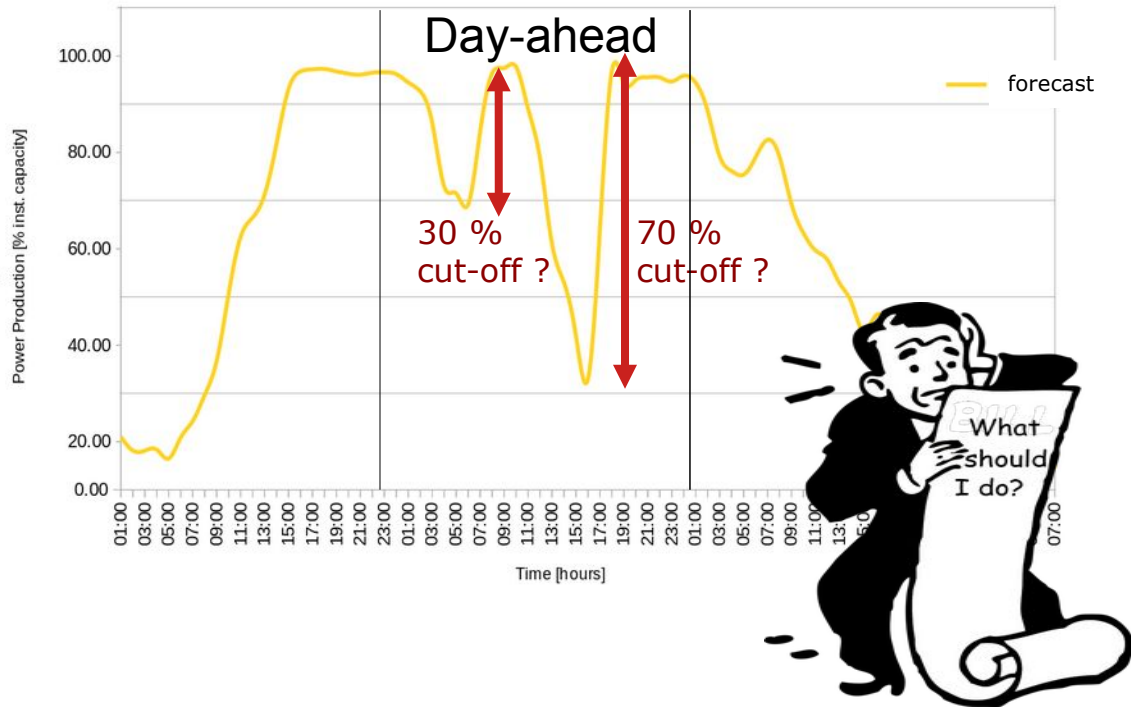**Do probabilistic forecast allow better adaptation to new environments?**
- Train in one environment and test behavior in new environment

Which cues ("predictors") do people use and why?

Simple heuristic decision tree?

```
              ┌─────────────────────────────────────┐
              │  Wind forecast close to threshold?   │
              └─────────────────────────────────────┘
               No ↙                        ↘ Yes
   ┌──────────────────────────┐      ┌──────────────────────────────────────┐
   │  No High-Speed Shut down │      │  Simultanous drop in power forecast?  │
   └──────────────────────────┘      └──────────────────────────────────────┘
                                      No ↙                    ↘ Yes
                    ┌──────────────────────────┐   ┌──────────────────────────────────┐
                    │  No High-Speed Shut down │   │  High-Speed Shut down with p = ?  │
                    └──────────────────────────┘   │                                    │
                                                    │  Depending on the uncertainty?     │
                                                    └──────────────────────────────────┘
```

Is it all about "dealing with extremes...." ?

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Scene: Decision to be made for Day-ahead:
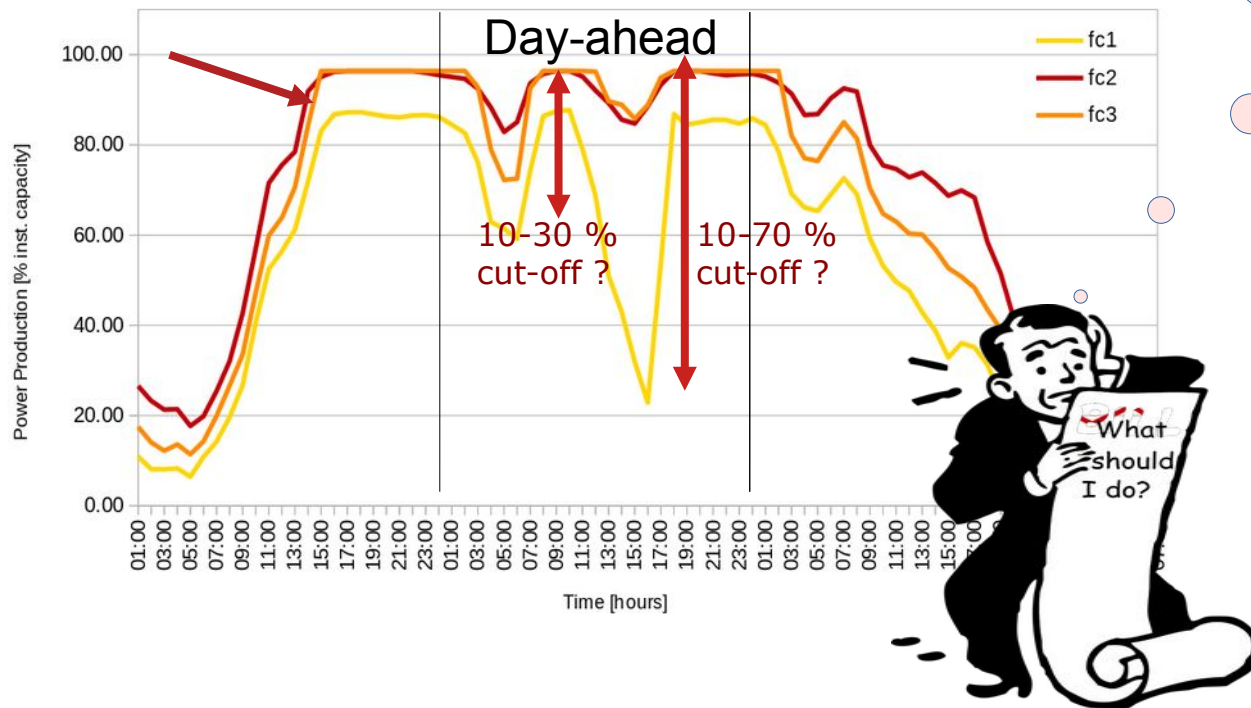Wind Power Forecast

Situation

→ Deterministic methods **"hide"** inherent uncertainty of forecast

→ Climate change requires more focus on **extremes**

→ **Increasing penetration levels** change system security levels

Dealing with Extremes....

Scene: Decision to be made for Day-ahead:
Wind Power Forecast

...these extra forecasts do not help me at all...

Situation

Randomly selected deterministic forecasts <u>do not provide a realistic uncertainty</u>!

Deterministic forecasts can deviate a lot or provide confidence, where there is no reason for confidence...!

Dealing with Extremes....

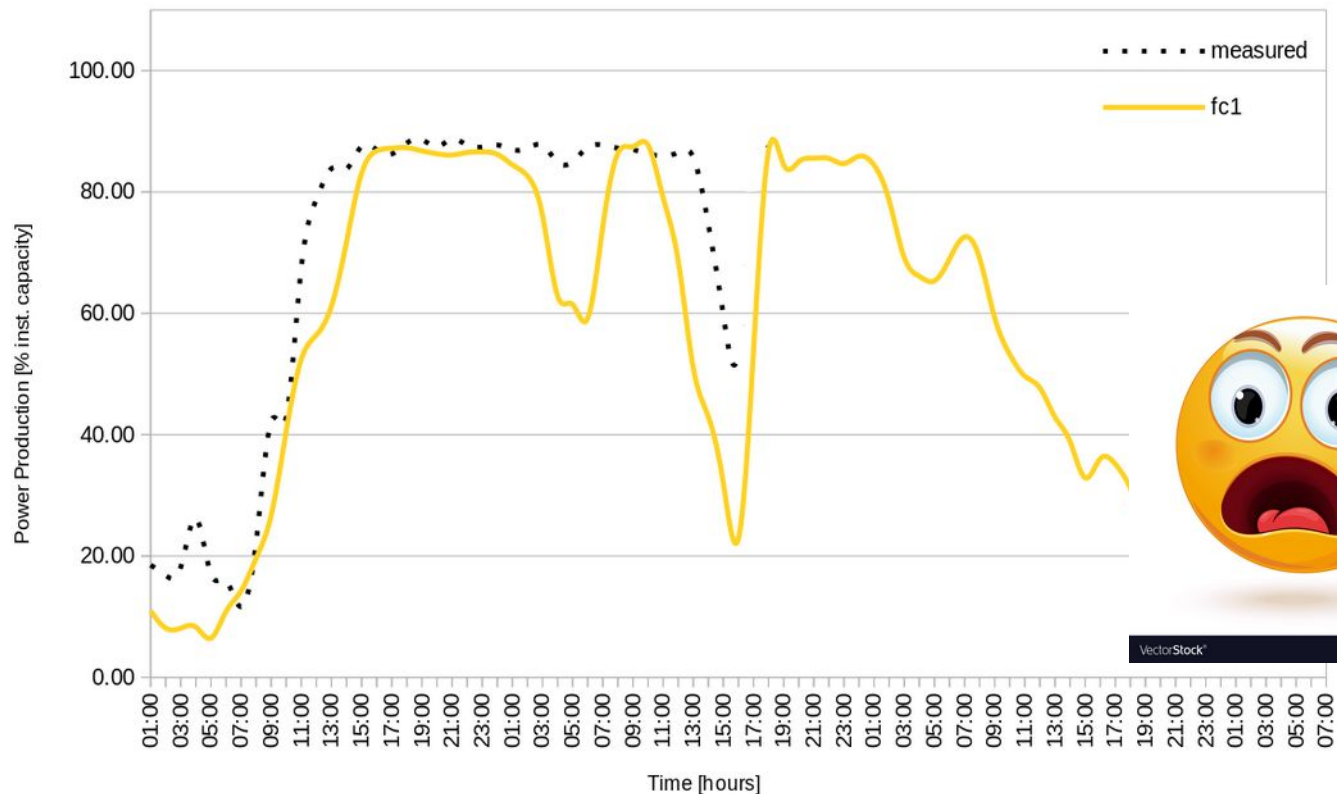Scene: Decision to be made for Intra-day:
Wind Power Forecast
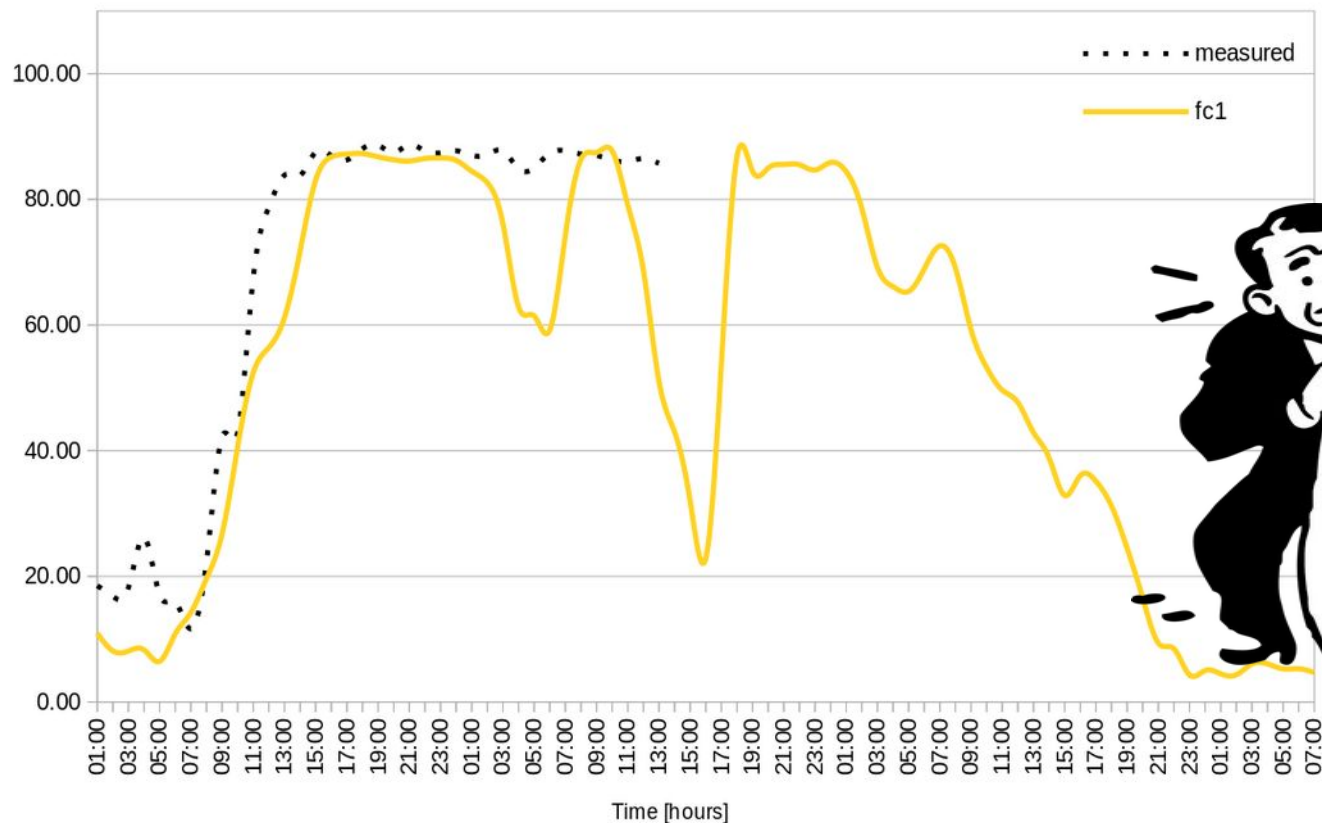
..if the power last night didn't cut off, it will probably also not do so now...

What worked yesterday does not automatically also work today... when it comes to weather uncertainty ...

Dealing with Extremes....

Scene: Decision to be made for Intra-day:
Wind Power Forecast

Decisions should not be made in extreme situations on the basis of a deterministic power forecast alone… !

Non-informed decision

Dealing with Extremes....

Scene: Decision to be made for Intra-day:
Wind Power Forecast **+ Uncertainty**

Legend:
- min – p10
- p10 – p20
- p20 – p30
- p30 – p40
- p40 – p50
- p50 – p60
- p60 – p70
- p70 – p80
- p80 – p90
- p90 – max

10% probability
of no/20% cut-off

10% probability
of no/25% cut-off

40% probability
of a 30% cut-off

40% probability
of a 70% cut-off
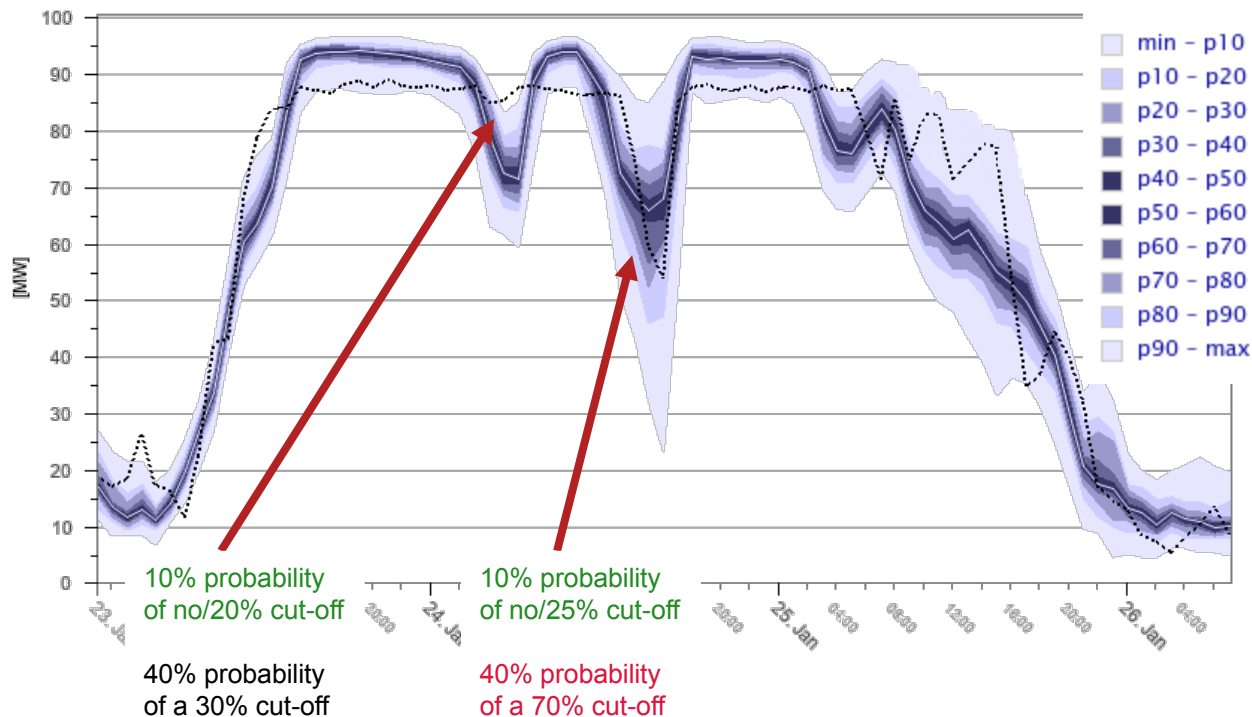
Situation:
In short-term balancing or grid operation:

Using uncertainty forecasts...

Does the uncertainty forecast alone give confidence and will I always make the correct decision.. ?

Dealing with Extremes….

Scene: Decision to be made for Intra-day:
Wind Power + Wind Speed Forecast **+ Uncertainty**

wind power

Legend:
- min – p10
- p10 – p20
- p20 – p30
- p30 – p40
- p40 – p50
- p50 – p60
- p60 – p70
- p70 – p80
- p80 – p90
- p90 – max

10% probability of no/20% cut-off

10% probability of no/25% cut-off

40% probability of a 30% cut-off

40% probability of a 70% cut-off

25m/s

wind speed
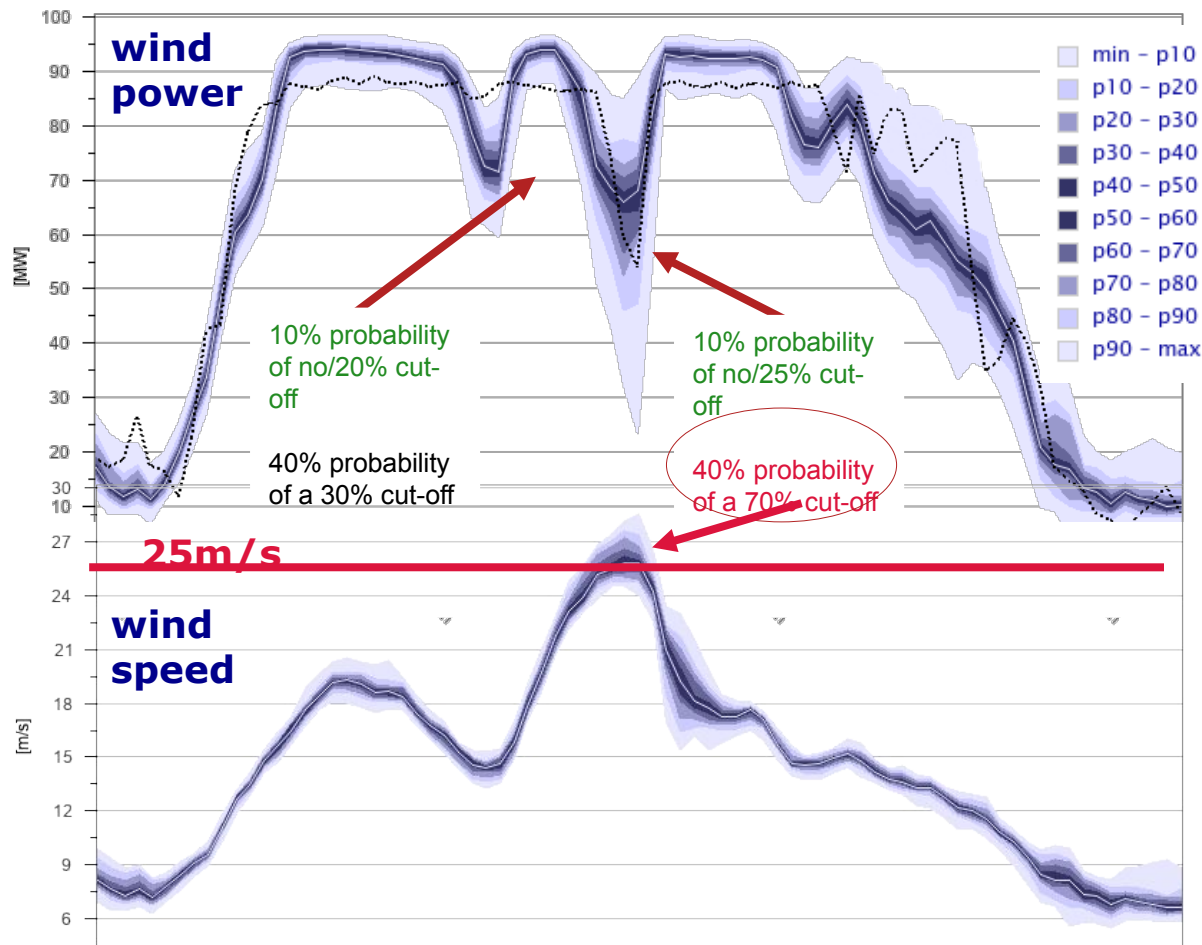
Solution ?

Does the uncertainty forecast alone solve the problem...

"Probabilistic Forecasting Games & Experiments" initiative:
Decision-making in extreme events

1. Experiment (2020)

Game: Decisions were to be made

- whether or not a high-speed cut-off takes place within the forecast time in 12 cases
- whether to trade 50% or 100% of the generating power of an offshore wind park

Decision Tools:

- 3 deterministic forecasts showing the wind power & wind speed
- probabilistic forecast showing wind power and wind speed inclusive uncertainty bands

2. Experiment (2021)

Game:

- 2 x times 20 cases (20 deterministic and 20 probabilistic cases)
- the participants make decisions based on either deterministic or probabilistic forecasts
- request on participant's confidence level regarding their decision
- real-time environment, e.g. participants may be surprised by forecasts that fail to warn or over-predict

Decision Tools:

Same as in 2020

Value of probabilistic power forecasts

How do professionals decide based on probabilistic wind & power forecasts?

Design & Analysis: Dr. Nadine Fleischhut*, Dr. Corinna Möhrlen** & Dr. Ricardo Bessa (INESCTEC)
Host of Experiment: *Max-Planck Insititute for Human Development, Hans-Ertl Center of Weather Reseach, Germany
Ensemble Forecasts: **MSEPS 75 Member EPS of WEPROG

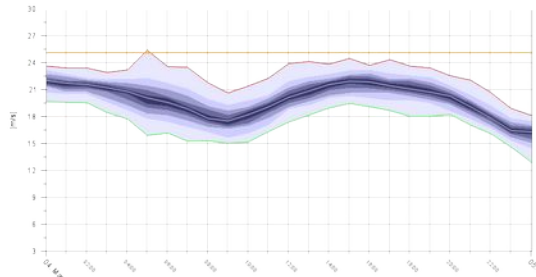Trade 100% or only 50% wind energy – given the risk of high-speed shutdown?

Power forecasts

Deterministic forecasts ➡ 1st Decision ➡ Probabilistic forecasts ➡ 2nd Decision
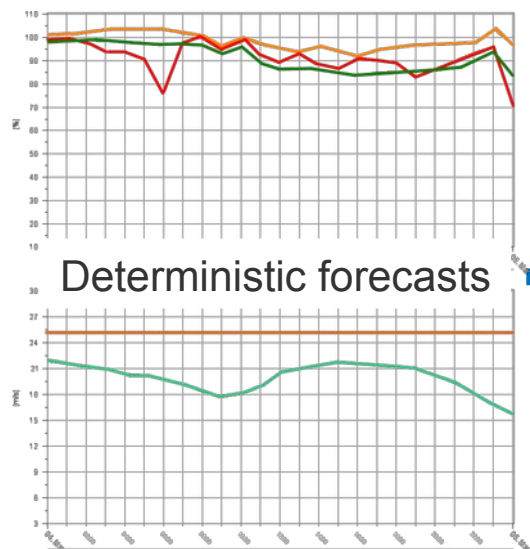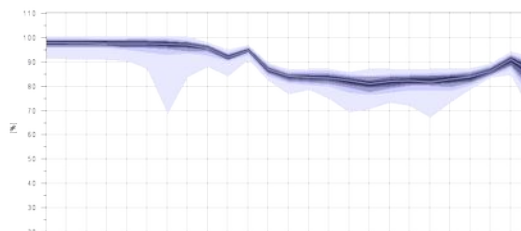
Wind forecasts

Cost function

	HSSD	No HSSD
Trading 100%	-5000	5000
Trading 50%	0	2500

How do professionals decide based on probabilistic wind/power forecasts?

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Trade 100% or only 50% wind energy – given the risk of high-speed shutdown?

	HSSD	No HSSD
Trading 100%	-5000	5000
Trading 50%	0	2500

Power forecast

Wind forecast

Power forecast

Wind forecast
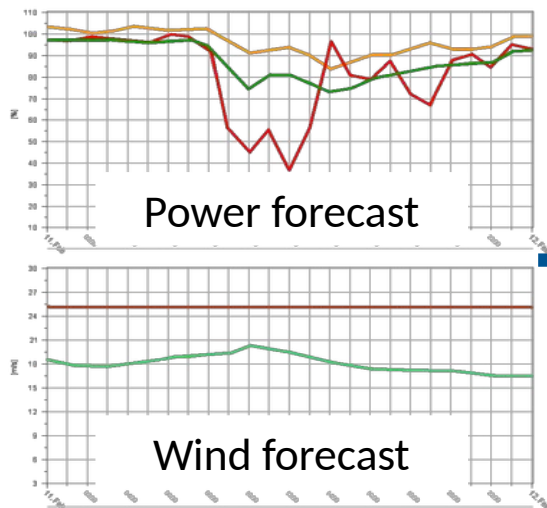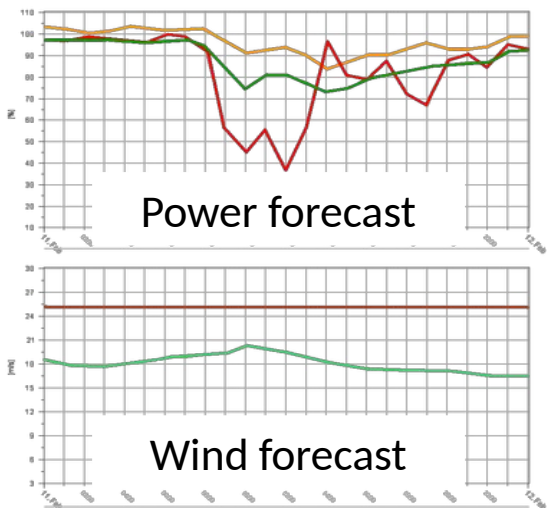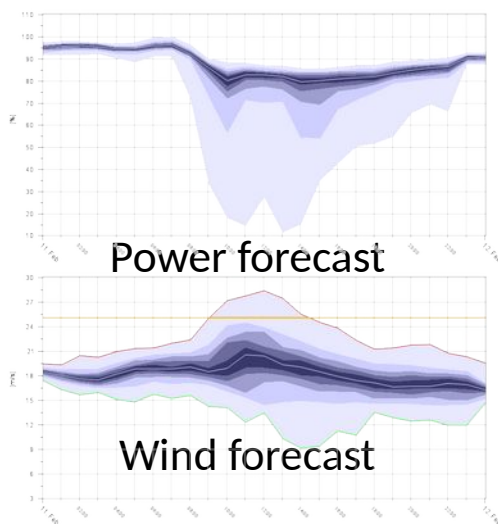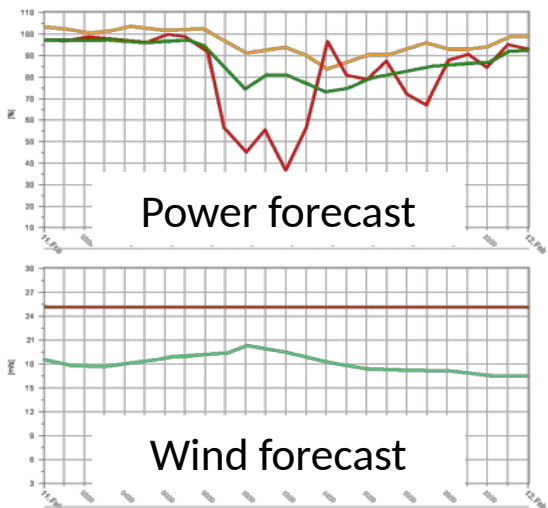
High-speed shutdown occurred.

If you traded 100%, you loose 5000 EUR
If you traded 50%, you neither loose or gain anything.

You chose to trade 100%.
You current balance therefore is: -5000
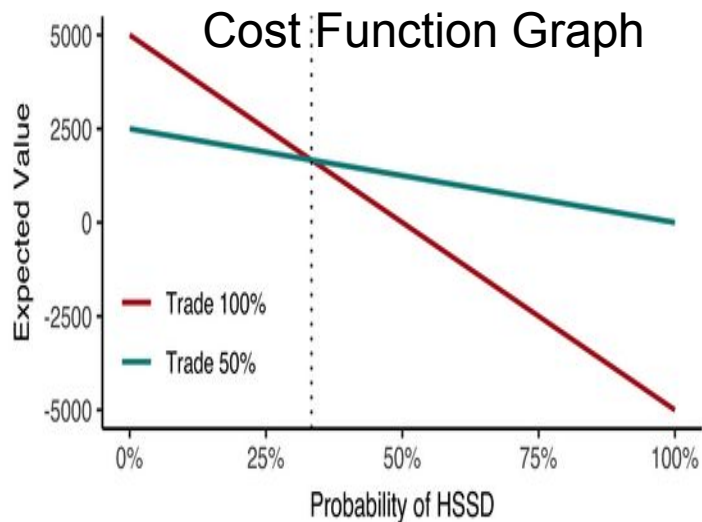
Trade 100%   Trade 50%

How confident are you?

Feedback

Aspects on Cost Functions from 1st Experiment: "Offshore wind power trading in extreme events"

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Cost Function Table

Trading	HSSD*	No HSSD*
100%	-5.000	5.000
50%	0	2.500

Cost Function Graph

Percentiles in Forecast graphs

- min – p10
- p10 – p20
- p20 – p30
- p30 – p40
- p40 – p50
- p50 – p60
- p60 – p70
- p70 – p80
- p80 – p90
- p90 – max

Some interesting aspects of the cost function:

- if the probability of a HSSD exceeds 33% trading 50% will give higher payoff

- if the probability of a HSSD < 33% trading 100% will give higher payoff

Could participants read this out ?
Deterministic forecasts: no information

Probabilistic forecasts:
→ percentiles provided information about the probability in wind and power !

Forecast Game: Offshore wind power decision making in extreme events

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ANALYSIS SUMMARY

For the game and this group of 120 participants*, using probabilistic Forecasts lead to...

Results in line with research, indicate benefits of probabilistic forecasts, but remember.... this was only a first game, not yet a structured experiment...

➔ Slightly higher income
➔ More correct decisions
➔ Less risky decisions

significance needs further testing

➔ Participants changed their mind in 16% of the cases
➔ 91% of participants changed their mind at least once

➔ Noticable: no one wanted to make decisions with deterministic forecasts alone!

*see slide 5

ANALYSIS – final balance -

Distribution and histogram of participants' final balance based on deterministic vs. probabilistic forecasts
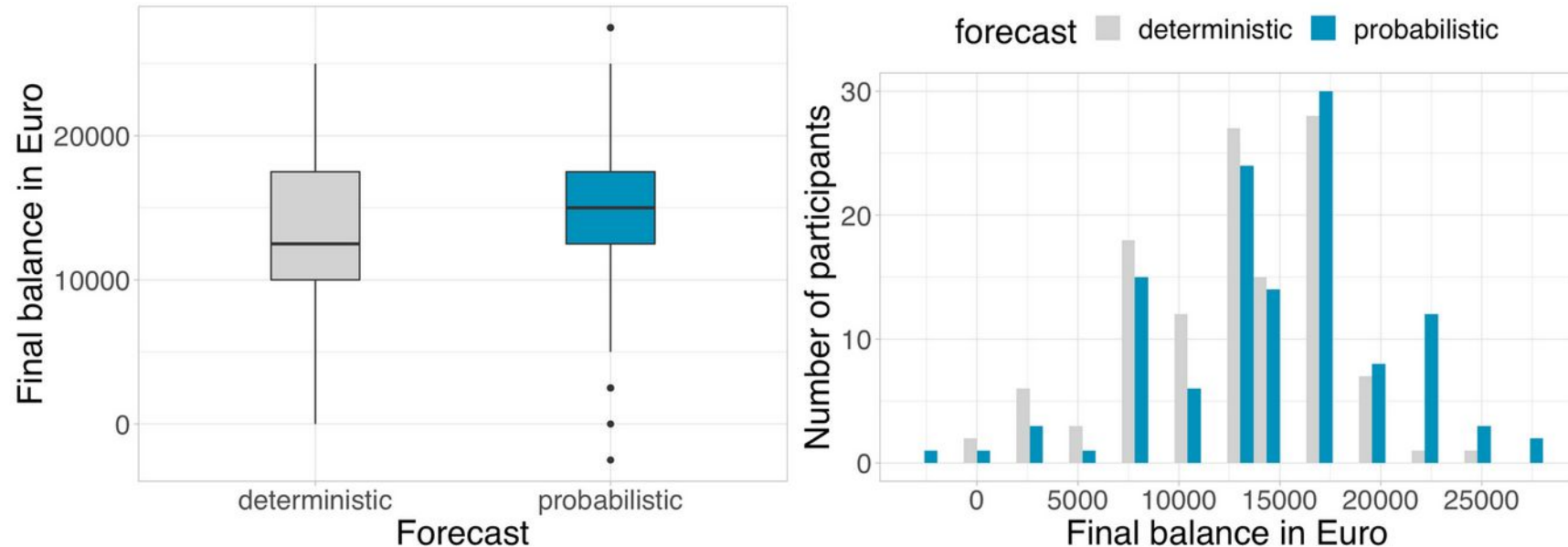
ANALYSIS – and the winner is…. -

The 2 best players with the highest income of 27.500€ have achieved this with the probabilistic forecasts. The best player with deterministic forecasts has achieved 25.000 €.

The table can be sorted by how much a participant made based on the deterministic or probabilistic forecast.

Show 75 entries   Search:

userID	probabilistic ▼	deterministic
fcstX1 _ 30	27500	17500
Kassandra _ 51	27500	17500
Oleaster _ 53	25000	17500
Howareyafrancis _ 37	25000	15000
Auracle _ 1	25000	10000
statwars _ 36	22500	20000
Gggrte _ 51	22500	20000
Tester101 _ 18	22500	17500
GatForecast _ 25	22500	17500
xinloi _ 52	22500	15000
argument _ 16	22500	12500
WindGuy _ 41	22500	12500
ads1512 _ 19	22500	12500
SmartyGuy _ 30	22500	12500
jb1234 _ 32	22500	12500

The table can be sorted by how much a participant made based on the deterministic or probabilistic forecast.

Show 75 entries   Search:

userID	probabilistic	deterministic ▼
yggdrasil _ 34	12500	25000
testtest _ 47	17500	22500
statwars _ 36	22500	20000
Gggrte _ 51	22500	20000
itzybilitzy _ 35	20000	20000
NikNik _ 9	17500	20000
mattttt _ 1	15000	20000
Anemoi _ 11	12500	20000
qwerty _ 5	12500	20000
fcstX1 _ 30	27500	17500
Kassandra _ 51	27500	17500
Oleaster _ 53	25000	17500
Tester101 _ 18	22500	17500
GatForecast _ 25	22500	17500
Sidhe1 _ 27	20000	17500
Trader 48	20000	17500

Forecast Game: Offshore wind power decision making in extreme events
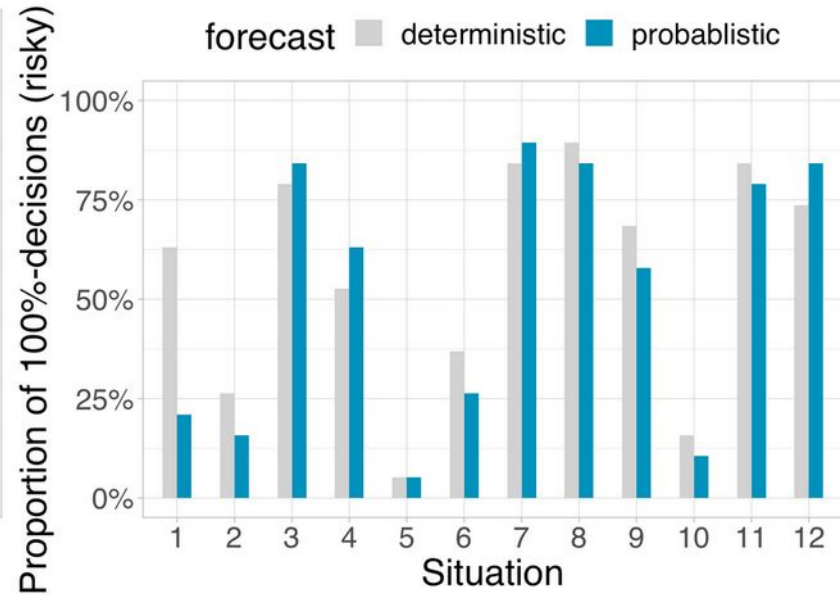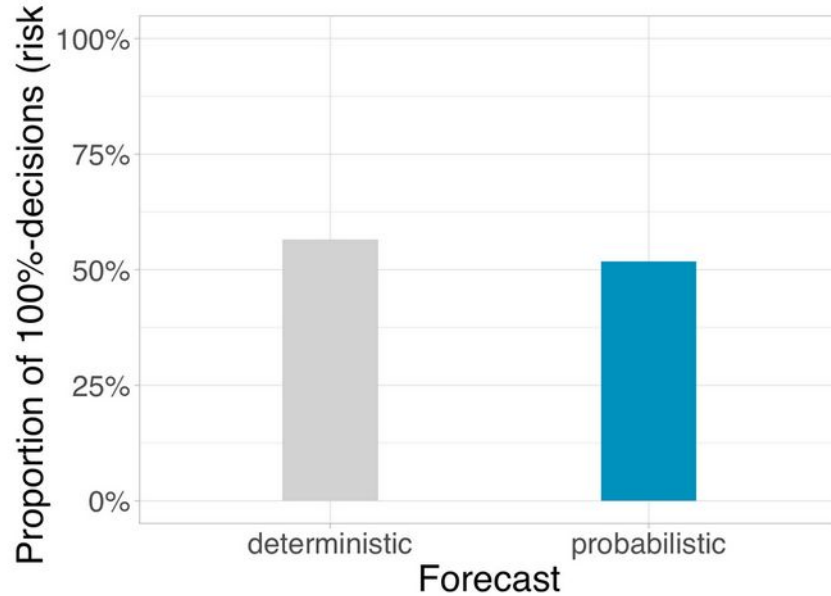
ANALYSIS – correct decisions -

Proportion of correct decisions based on deterministic vs. probabilistic forecasts
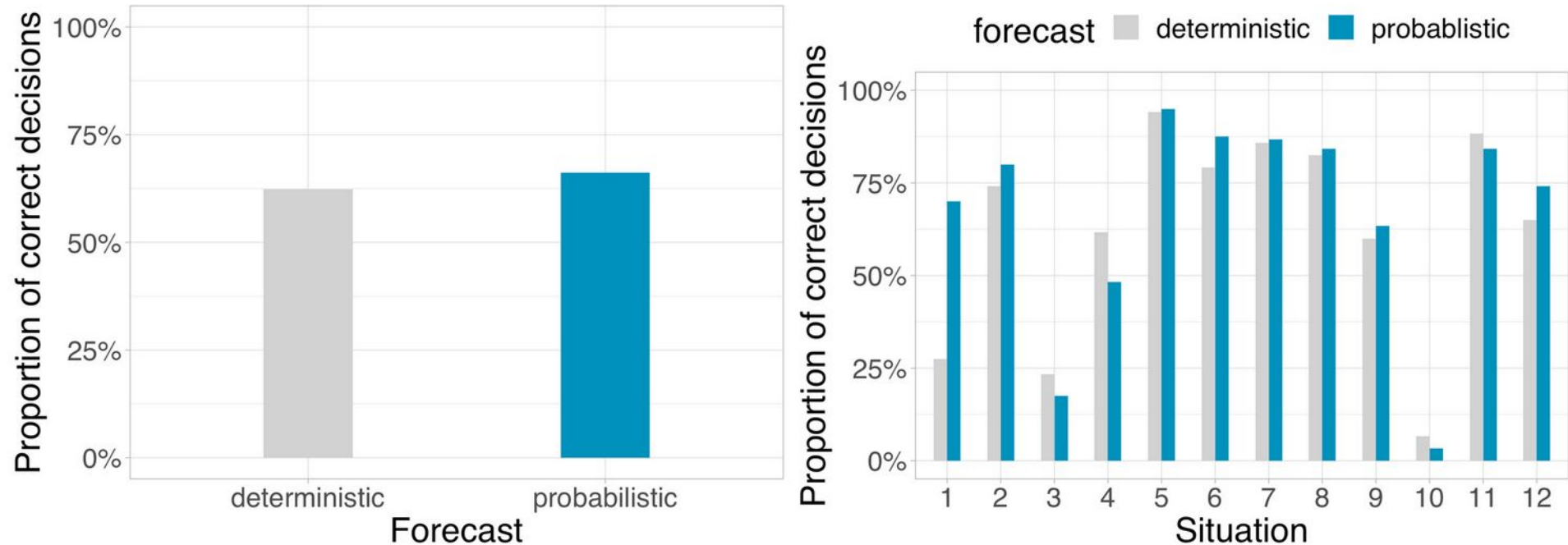
Forecast Game: Offshore wind power decision making in extreme events
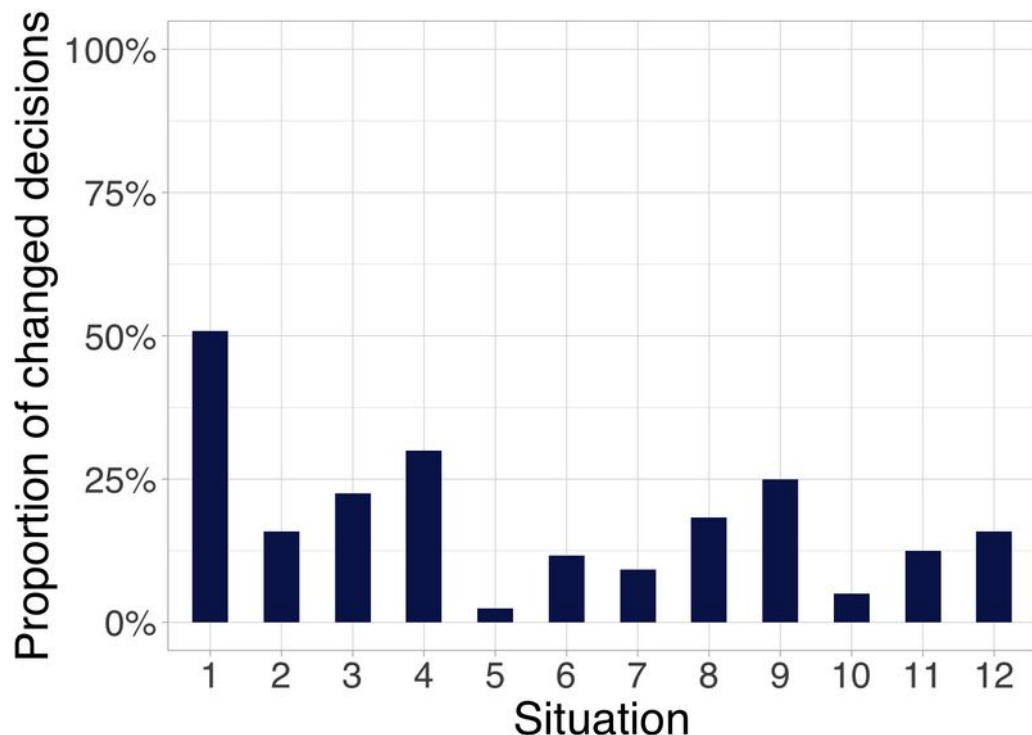
ANALYSIS – risky decisions -

ANALYSIS – changed decisions -

Proportion of changed decisions based on the probabilistic forecast

Across all decisions, **participants changed** their **mind in 18 % of the situations**.

On an individual level, **91 % of the participants changed their mind at least once** based on the probabilistic forecast.

task 36

ANALYSIS of Questions – preferred information -

Histogram of participants' preferred information
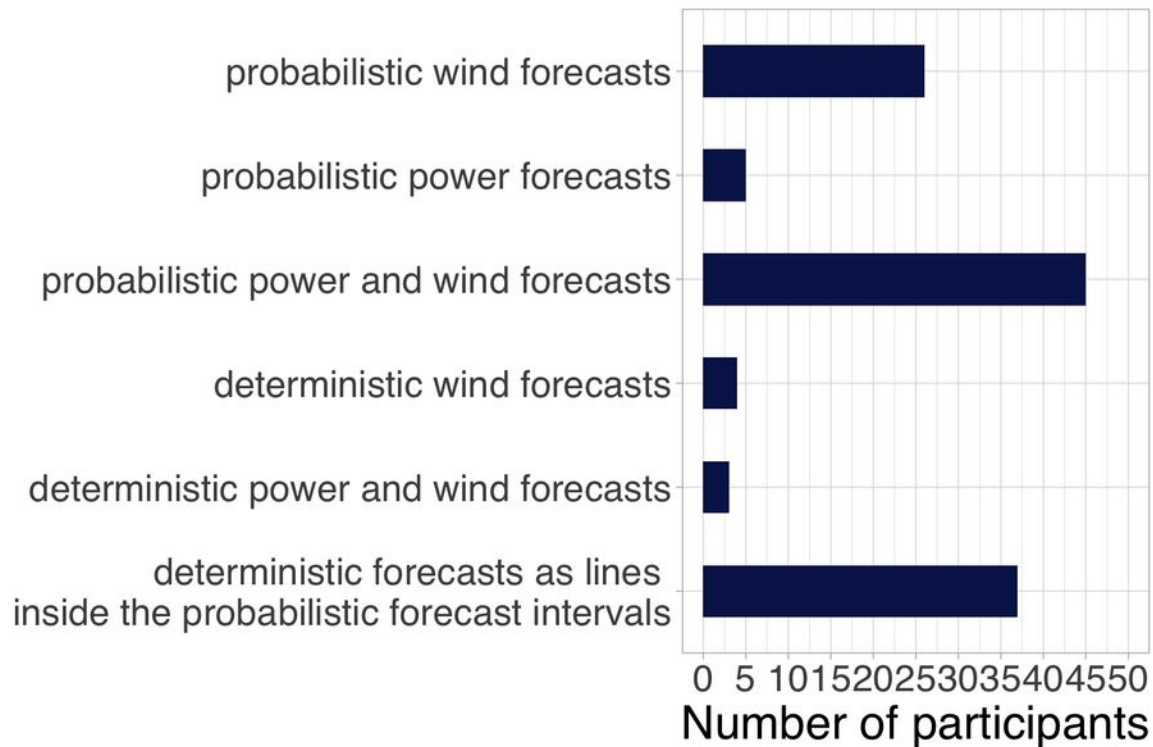
No one preferred to make decisions based on deterministic power forecast alone.

How do professionals decide based on probabilistic wind & power forecasts?
Design & Analysis: Dr. Nadine Fleischhut*, Dr. Corinna Möhrlen**
Host of Experiment: *Max-Planck Insititute for Human Development, Hans-Ertel Center for Weather Research, Germany
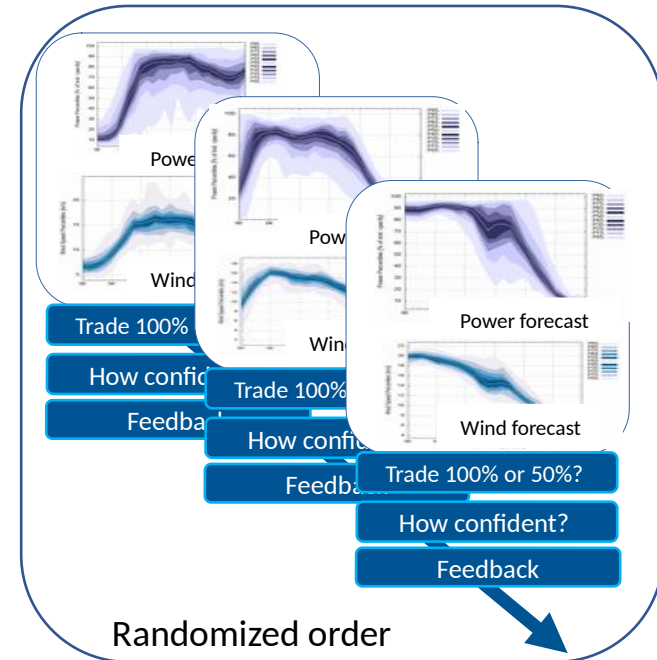Ensemble Forecasts: **MSEPS 75 Member EPS of WEPROG

Trade 100% or only 50% wind energy – given the risk of high-speed shutdown?

Each participant
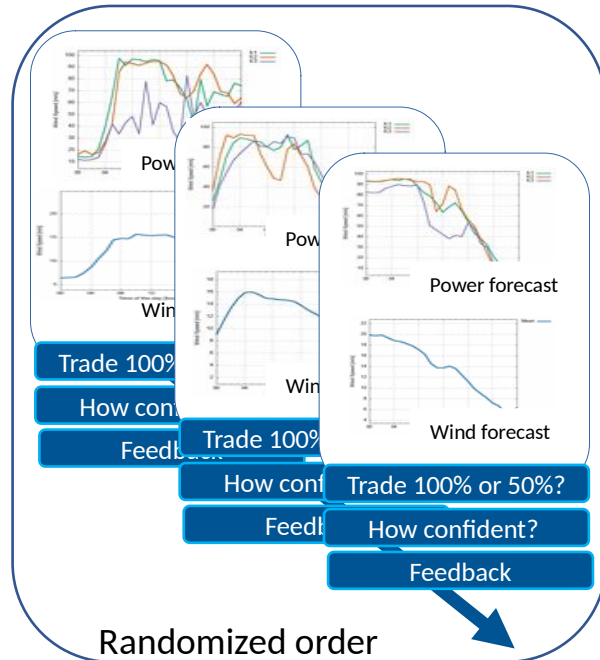
Blocks randomized

20 decision situations with deterministic forecasts

20 decision situations with probabilistic forecasts

Wind Power Trading: What is the value of probabilistic forecasts for decision making?
How well can you use probabilistic or determinstic forecasts for simple trading decisions?
Find out by participating in a short decision experiment (ca. 20-30 minutes).

The study is a cooperation of the IEA Task 36 WP3 and project WEXICOM at the Max Planck Institute for Human Development.

Start

Link for the 2ⁿᵈ experiment

BETA Version **Open to Play!**

https://arc-vlab.mpib-berlin.mpg.de/wind-power/experiment/

Summary and Take-away

How can probabilistic wind/power forecasts benefit decision making?

Tailor information: Probabilistic information can improve decisions
- Define the decisions that have to be made precisely

Risk communication: Improve risk perception via transparent representations
- Evidence-based design and evaluation of different representations

Decision support: Define how to decide based on probabilistic information
- Provide cues for interpretation (e.g. highlight critical thresholds)
- Put information in perspective (e.g. comparision, typical distribution)
- Allow users to develop decision strategies based on realistic experience
- Provide simple and robust heuristics /decision strategies for users

THANK YOU

Follow us:

Project webpage http://www.ieawindforecasting.dk/

Task-page: https://www.ieawindforecasting.dk/work-packages/workpackage-3

Publications: https://www.ieawindforecasting.dk/publications

YouTube Channel: https://www.youtube.com/channel/UCsP1rLoutSXP0ECZKicczXg

Contact WP Leader:
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Dr. Ricardo Bessa, INESC TEC
ricardo.j.bessa@inesctec.pt

Contact Operating Agent:
Dr. Gregor Giebel, DTU Wind
grgi@dtu.dk

Link for the 2nd experiment

BETA Version **Open to Play!**

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Contact Behavioural & Cognitive Scientist:
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Hans-Ertel Center for Weather Research
Nadine Fleischhut <fleischhut@mpib-berlin.mpg.de>